Morphological Characteristics of Adult Male Handball Players Considering Five Levels of Performance and Playing Position

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ABSTRACT

This study aims 1- to describe and compare the anthropometric characteristics of male handball players from different levels of performance, and 2- to identify the morphological variables that allow differentiation of the level of performance for each individual playing position. A total of 212 male handball players (age, 23.6±5.2 years) were included in this study, and divided into five levels of performance for comparison. The playing position of each player was recorded. All participants were tested during the 2008–2009 Portuguese handball season. Twenty-eight anthropometric measures were taken by a group of anthropometrics accredited by International Society of the Advance of Kinanthropometry. Body composition, fat mass and muscle mass were calculated from the equations proposed by Faulkner[26], Yuhasz[28], Durnin and Womersley[25], Jackson and Pollock[29], Matiegka[33], Heymsfield, McManus, Smith, Stevens and Nixon[34], Martin, Spenst, Drinkwater and Clarys[21], Doupe, Martin, Searle, Kriellaars and Giesbrecht[35] and Lee, Wang, Heo, Ross, Janssen and Heymsfield[36]. The research findings showed that the morphological optimization is important to have success in handball.

Key words: *anthropometrics, body composition, handball, performance, success*

Introduction

The development of sport has guided the Sport Sciences researchers to the study of excellence in sport performance and in particular to the characteristics and requirements of each sport. However, to meet these requirements, each individual must hold a set of specific characteristics similar to the group he belongs[1]. Among this set of characteristics, necessarily multivariate (e.g., general and specific physical fitness, technical and tactical performance during the game), the most studied until now are undoubtedly the anthropometric characteristics.

In the last years, the study of anthropometry and sport performance have showed: 1- how morphological prototypes are important for success, within and among sports; 2- a higher morphological variability in some sports than others; 3- that athletes who have or have acquired an optimal anthropometric profile for a specific event are more likely to succeed; and 4- that morphological optimization is useful to evaluate the training status, and the talent selection in male and female athletes[2,3]. In other words, the morphological information seems to be important to improve athletic performance[4].

In addition to the studies of morphological differences between Olympic sports and between adult male handball players and non-athletes, literature also reports studies about: 1- the typical biological characteristics of handball players[5–7]; 2- the adaptive response of the organism to physical training[8–10]; 3- the morphological differences between players from teams exhibiting different levels of performance[11–14]; 4- the differences between playing positions[15–17]; and, 5- the differences between players with the same position but different levels of performance[18–20].

It seems that anthropometric profiles of elite athletes can provide a closer view of the morphological requirements necessary to compete at a top level, in handball. So, having in consideration what was said and the lack of data about contemporary Portuguese handball players, the present study aims: 1- to describe and compare the anthropometric characteristics of male handball players from

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different levels of performance, and 2- to identify the morphological variables that allows to discriminate the level of performance for each individual playing position (i.e., goalkeeper, wing, backward left/right, backward center and pivot).

Methods

Study procedure and subjects

The experimental protocol was in accordance with the Declaration of Helsinki and was approved by the Scientific and Ethical committees of Faculty of Human Kinetics, Technical University of Lisbon, Portugal. Before inclusion in the study, the objectives and procedures were explained to subjects, and written informed consent was obtained from them.

A total of 212 male handball players (age, 23.6±5.2 years) were included in this study. Playing status (i.e., levels of performance) were recorded for comparison, namely: 1- Professional Handball Championship (LPA) – Top elite (TE; N=37; age, 25.9±4.7 years); 2- 1st Portuguese Handball Division (Portuguese Handball Federation, PO.01) – Moderate elite (ME; N=54; age, 26.4±4.9 years); 3- 2nd or 3th Portuguese Handball Division (Portuguese Handball Federation, PO.02 and PO.03) – Sub elite (SE; N=35; age, 24.3±4.2 years); 4- Regional (1st division, Lisbon Handball Association) and Academic level – Moderate trained (MT; N=33; age, 24.2±5.0 years); 5- 1st Portuguese Junior Handball Division (Portuguese Handball Federation, PO.04) – Junior Elite (JE, N=53; age, 18.2±0.9 years). Top elite players can be considered as one of the Portuguese leading professional handball teams because they were the Portuguese Champions and vice-champions. Playing position was also recorded for each participant as goalkeeper (GK, N=34), wing (W, N=65), backward left/right (BLR, N=46), backward center (BC, N=38) or pivot (Pi, N=29). All participants were tested during the 2008–2009 Portuguese handball season (2009, February and March) (Table 1).

Anthropometric measures

Twenty-eight anthropometric dimensions were obtained. The dimensions included five basic measures, nine skinfolds (mm), seven girths (cm), two breadths (cm) and five lengths (cm). The five basic measures were stature (cm), body mass (kg), sitting height (cm), arm span (cm) and hand span (cm). The nine skinfolds were subscapular, triceps, biceps, chest, iliac crest, supraspinale, abdominal, front thigh and medial calf. The seven girths were arm (relaxed and, flexed and tensed), forearm (maximum), chest (mesosternale), waist (minimum), thigh (mid-troch-tib. lat.) and calf (maximum).

It is also important to highlight that the protocols used by some prediction equations, such as Martin et al.[21], do not uses the thigh girth referenced by ISAK (i.e., inguinal-patellar). However, the reviewed literature showed that some studies use Martin et al.[21] equation with the ISAK thigh girth. This consideration makes the body composition results difficult to compare, since they appear quite inflated (e.g., Hassan et al.[14]). So, to solve this problem we adjusted the original measure of thigh girth (mid-troch-tib. lat.) to the ISAK protocol measure. A subsample (N=31) was used to calculate a coefficient of adjustment (R=0.986). The two bone breadths were biacromial and biiliocristal. The five lengths were acromiale-dactylion, acromiale-radiale, radiale-stylion, radial-dactylion and midstylion-dactylion.

Measurements included in the anthropometric profile were obtained following the protocol in Marfell-Jones et al.[22], with the exception of arm span (perpendicular distance between the longitudinal planes of the left and right dactyilon sites with the subject standing with the back to the wall with both arms abducted to 90º, the elbows and wrists extended and the palms facing directly forward), hand span (the greater distance between the longitudinal planes of the 1st and 5th fingers), chest skinfold (the skinfold measurement taken with the fold running obliquely in the mean distance between the breast nipple and the axilla fold), acromiale-dactylion length (the linear distance between the acromiale and dactylion sites) and radiale-dactylion length (the linear distance between the radiale and dactylion sites).

Anthropometric measurements were obtained using portable measurement devices. Stature and heights were measured without shoes and head covers, using a portable Anthropometer (Anthropometric Kit Siber-Hegner Ma-

TABLE 1
DISTRIBUTION OF SUBJECTS [N(%)] ACCORDING TO LEVEL OF PERFORMANCE AND PLAYING POSITION IN HANDBALL TEAM.

Playing Positions	Level of Performance					Total
	JE	MT	SE	ME	TE	
GK	10 (29.4%)	4 (11.8%)	3 (8.8%)	10 (29.4%)	7 (20.6%)	34 (100%)
W	18 (27.7%)	12 (18.5%)	14 (21.5%)	14 (21.5%)	7 (10.8%)	65 (100%)
BLR	10 (21.7%)	7 (15.2%)	7 (15.2%)	10 (21.7%)	12 (26.1%)	46 (100%)
BC	8 (21.1%)	3 (7.9%)	8 (21.1%)	11 (28.9%)	8 (21.1%)	38 (100%)
Pi	7 (24.1%)	7 (24.1%)	3 (10.3%)	9 (31.0%)	3 (10.3%)	29 (100%)
Total	53 (25.0%)	33 (15.6%)	35 (16.5%)	54 (25.5%)	37 (17.4%)	212 (100%)

chines SA GPM, 2008) calibrated to the nearest 0.1 cm. Body mass was measured with subjects wearing light clothing and without shoes, to the nearest 0.5 kg, using a scale (Body Mass Scale Vogel & Halke – Germany – Secca model 761 7019009, 2006) calibrated with known weights. Skinfold thickness was obtained using a caliper (Skinfold caliper Rosscraft Slim Guide 2001), lengths and diameters using a large sliding calliper (Anthropometric Kit Siber-Hegner Machines SA GPM, 2008), girths using a »Rosscraft Anthropometric Tape«.

All measures were taken by a group of anthropometrics accredited by ISAK, under the supervision of a ISAK Level 4.

Assessment of body composition

The study of body composition in this work considered fat mass and muscle mass. Numerous methodological assumptions and sample-specificities govern the conversion of linear surface measurements into tissue masses and restrict the value of many body composition equations. In other words, predicting fat or muscle tissue masses is obviously important but also problematic.

To provide a more valid estimate of body fat (confirmed in healthy young men and women by Eston et al.[23]), Reilly et al.[24] suggested the use of the equation proposed by Durnin and Womersley[25] as described by Hasan et al.[14]. However, in previous studies with adult male handball players, the % body fat was estimated using the equations proposed by Faulkner[26] like in Chamorro et al.[27], Yuhasz[28] as confirmed by Çakieoğlu et al.[6], or derived from equation proposed by Jackson and Pollock[29] like it is observed in the studies of Bezerra and Simão[19], Glaner[18], Gorostiaga et al.[30] and Vasques et al.[12]. As, Durnin and Womersley[25] and Jackson and Pollock[29] equations predict the body density to convert it to relative body fat it was used the formula of Siri[31].

In opposition, a small number of studies focused the muscle mass of male handball players. Nevertheless, according to Spenst et al.[32], the Martin et al.[21] equation appears to provide the best estimate of skeletal muscle mass of competitive male athletes, i.e., it is the only cadaver-validated equation, it provides values that are consistent with all known dissection data and it gives appropriate results when applied to young men with a wide range of muscularity. This equation has been used recently by Hasan et al.[14] in the study of »anthropometric profile of elite male handball players in Asia«. However and as a complementary evaluation the estimated muscle mass (absolute and relative) was also calculated according to Matiegka[33], Heymsfield et al.[34], Doupe et al.[35] and Lee et al.[36].

Statistical analyses

All calculations were performed using Microsoft Excel (Microsoft, Seattle, Washington, USA) and the SPSS statistical package (Statistical Package for the Social Sciences Inc, version 17.0, Chicago, Illinois). Descriptive and comparative data are presented, and group data are expressed as means and standard deviations ($\overline{X}$±SD) for all dependent variables. Two different sets of analyses were undertaken. First, dataset was analyzed using a univariate analysis of variance (ANOVA One-Way) in which playing status was the between-participant variable, followed-up by a multiple comparisons test (Tukey HSD Post Hoc) whenever appropriate, to isolate any difference between playing status. Second, stepwise discriminant function analysis were used to determine which combination of measures best discriminated (in all sample and for each playing position group) the playing status of each studied group. For all analyses, 5% was adopted as the significance level.

Results

First, analysis revealed significant differences between the levels of performance in linear dimensions and body composition measures, especially between the top elite and all the others four groups (all in favor of the top elite players). Differences were particularly evident for basic measures (Range: body mass =+3.98 kg to +8.41 kg; stature =+8.68 cm to +5.08 cm; sitting height =+4.78 cm to 1.81 cm; arm span =+11.25 cm to +5.84 cm; hand span =+1.09 cm to +0.43 cm), subcutaneous fat tissue (in mm; Range: triceps =–5.66 to –1.41; biceps =–3.4 to +0.2; chest =–3.49 to 0.37; front thigh =–6.47 to –2,0; medial calf =–4.24 to 0.17), girth measures (in cm; Range: arm relaxed =+1.93 to +0.94; arm tensed =+2.52 to 1.20; forearm =+1.90 to 0.73; chest =+6.56 to +1.65; waist =+4.70 to –0.06), transversal dimensionality (biacromial breadth, range =+1.82 cm to +1.12 cm), upper limb lengths (in cm; Range: acromiale-dactylion =+7.20 to 6.33; acromiale-radiale =+2.27 to 1.39; radiale-dactylion =+2.70 to 1.28; midstylion-dactylion =+0.80 to +0.19), muscle mass (Range: absolute =+9.82 kg to +1.41 kg); relative =+6.99% to –1.79%), fat mass (Range: absolute =–1.51 kg to –6.61 kg; relative =–4.32% to –0.34%) and free fat mass (Range: absolute =+15.01 kg to +4.23 kg; relative =+10.22% to +0.98%). The differences between junior elite and moderate trained players were significant just for the chest skinfold (JE: –3.86 cm, $p<0.05$) and fat mass (JE: absolute =–5.10 kg, $p<0.01$; relative =–3.98%, $p<0.05$). Also junior elite and moderate elite players presented different medial calf skinfolds values (all in favor of moderate elite; ME=–4.41 mm, $p<0.01$), different girths values (ME: forearm =+0.95 cm; chest =+4.91 cm; waist =+4.76 cm; all, $p<0.01$) and different absolute muscle mass values (ME: range =+3.41 kg to +0.02 kg). Also significant differences were observed between moderate trained players and moderate elite players (in favor of the last group of players), namely in subcutaneous fat tissue (ME: triceps sk=–4.25 mm; biceps sk=–3.60 mm), forearm girth (ME:+1.17 cm), absolute muscle mass (ME: range =+5.45 kg to +3.69 kg), absolute fat mass (ME=–3.47 kg) and absolute free fat mass (ME: range =+7.89 kg to +5.05 kg). These results are presented in Table-2 and Table-3, and show that: 1- anthropometrical characteristics are strongly related to

TABLE 2
DESCRIPTIVE STATISTICS (X±SD), ANOVA AND TUKEY HSD *POST-HOC* TESTS RESULTS OF ANTHROPOMETRIC VARIABLES

Variables	Descriptive statistics					ANOVA	JE	JE	JE	JE	MT	MT	MT	SE	SE	ME
	JE	MT	SE	ME	TE	p	MT	SE	ME	TE	SE	ME	TE	ME	TE	TE
Body mass (kg)	80.06±12.42	78.18±15.28	79.14±10.71	82.61±11.27	86.59±10.52	*				*						
Stature (cm)	179.56±15.59	178.56±6.52	179.87±6.25	182.16±6.50	187.24±5.29	**				**			**		*	
Sitting height (cm)	95.08±13.02	92.11±3.60	93.37±2.75	94.23±3.38	96.89±2.69	NS							*			
Arm span (cm)	182.30±14.54	179.88±6.88	181.02±19.49	185.29±8.24	191.13±6.41	**				**			**		**	
Hand span (cm)	22.17±1.24	22.03±1.78	22.62±1.28	22.69±1.26	23.12±1.31	**				*			**			
Triceps skinfold (mm)	11.74±5.52	15.09±9.68	12.33±6.69	10.84±5.42	9.43±5.18	**						*	**			
Biceps skinfold (mm)	5.41±3.31	7.70±8.32	5.39±4.01	4.10±2.17	4.30±1.98	**						**	**			
Chest skinfold (mm)	7.62±3.67	11.48±8.59	8.91±4.94	9.00±4.71	7.99±5.75	*	*									
Front thigh skinfold (mm)	14.88±10.34	17.83±10.16	14.53±5.32	13.36±5.45	11.36±4.85	*							**			
Medial calf skinfold (mm)	11.81±9.01	10.97±6.53	9.70±5.36	7.40±3.16	7.57±3.01	*			**	*						
Arm girth (relaxed) (cm)	31.83±2.82	32.09±3.19	31.71±2.25	32.70±2.86	33.64±1.82	**				*					*	
Arm girth (tensed) (cm)	33.55±2.54	33.32±2.78	33.21±1.89	34.53±2.68	35.73±1.98	***				***			***		***	
Forearm girth (cm)	28.12±1.67	27.90±1.96	28.43±1.49	29.07±1.84	29.80±1.45	***			**	***		*	***		**	
Chest girth (cm)	96.98±10.60	100.62±8.18	99.12±6.21	101.89±7.18	103.54±5.92	**			**	**						
Waist girth (cm)	81.43±9.07	84.45±10.30	84.52±7.03	86.19±7.22	86.13±7.00	*			**							
Biacromial breadth (cm)	41.54±2.28	40.84±3.13	41.42±2.50	41.10±2.27	42.66±2.76	*							*			*
Acromiale-dactylion length (cm)	77.91±3.61	76.23±3.02	78.02±3.04	79.39±4.03	82.56±10.03	***				**			***		**	*
Acromiale-radiale length (cm)	33.51±1.84	32.92±1.68	33.62±1.70	33.80±2.39	35.19±1.49	***				**			***		**	**
Radiale-dactylion length (cm)	45.37±2.20	44.56±1.97	45.98±2.77	45.49±2.38	47.26±2.22	***				**			***			**
Midstylion-dactylion length (cm)	20.05±1.00	19.75±0.85	20.31±0.98	20.36±1.26	20.55±0.96	*							*			

*p<0.05; **p<0.01; ***p<0.001; NS, not significant

TABLE 3
DESCRIPTIVE STATISTICS (X±SD), ANOVA AND TUKEY HSD *POST-HOC* TESTS RESULTS OF BODY COMPOSITION VARIABLES

Variables	Descriptive statistics					ANOVA	JE	JE	JE	JE	MT	MT	MT	SE	SE	ME
	JE	MT	SE	ME	TE	p	MT	SE	ME	TE	SE	ME	TE	ME	TE	TE
Muscle mass[33] (kg)	38.63±6.42	37.25±4.74	39.53±4.02	41.48±5.40	44.43±4.47	***			*	***		**	***		**	
Muscle mass[34] (kg)	32.56±5.91	30.52±4.91	31.83±4.28	35.97±6.87	40.34±5.48	***			*	***		***	***	**	***	**
Muscle mass[21] (kg)	46.12±8.39	44.30±6.00	47.06±4.91	48.44±6.48	51.92±4.91	***				***		*	***		*	
Muscle mass[35] (kg)	40.33±7.08	38.59±4.53	41.07±4.60	43.37±6.24	46.54±5.03	***				***		**	***		**	
Muscle mass (1st Equation)[36] (kg)	35.65±4.30	33.88±2.95	35.56±3.00	37.57±4.21	40.06±3.65	***				***		***	***		***	*
Muscle mass (2nd Equation)[36] (kg)	35.06±3.53	33.93±4.06	34.26±2.82	35.08±2.97	36.49±2.63	*							*	*		
Muscle mass[33] (%)	48.40±5.34	48.31±4.94	50.30±4.10	50.33±2.95	51.54±3.68	**				**			*			
Muscle mass[34] (%)	40.84±5.42	39.94±7.69	40.66±5.80	43.57±6.20	46.93±6.17	***				***			***	***		
Muscle mass[35] (%)	50.52±5.90	50.24±6.34	52.44±6.87	52.59±4.26	54.02±4.71	*				*			*			
Muscle mass (2nd Equation)[36] (%)	44.17±3.03	43.92±2.97	43.60±2.45	42.77±2.44	42.38±2.13	**				*						
Fat mass[29] (kg)	13.43±6.31	18.53±7.83	16.10±5.49	15.10±5.53	11.92±5.04	***	**						***		*	
Fat mass[25] (kg)	19.17±5.01	22.11±6.16	19.74±4.84	18.64±5.69	16.54±4.64	**						*	***			
Fat mass[29] (%)	10.87±5.60	14.85±7.81	13.02±5.51	12.61±5.26	10.53±5.46	*	*						*			
Free fat mass[26] (kg)	68.77±8.81	65.03±7.96	67.39±7.06	70.80±8.07	75.03±7.38	***				**		*	***		**	
Free fat mass[28] (kg)	68.69±8.73	65.36±8.34	67.68±7.21	71.20±8.22	75.53±7.60	***							*			
Free fat mass[29] (kg)	66.63±13.00	59.66±14.80	63.04±9.34	67.50±11.43	74.67±9.65	***				*		*	***		***	*
Free fat mass[25] (kg)	60.88±12.25	56.07±14.48	59.40±9.03	63.96±11.53	70.05±10.39	***				**		*	***		**	
Free fat mass[28] (%)	86.20±4.38	84.51±5.85	85.89±3.84	86.47±3.53	87.45±3.19	NS							*			
Free fat mass[29] (%)	82.97±9.00	76.07±10.23	79.74±6.10	81.56±6.97	86.29±5.18	***	**						***		**	*
Free fat mass[25] (%)	75.73±6.45	71.26±8.37	75.06±4.90	77.18±7.51	80.77±5.43	***	*			**		**	***		**	

*p<0.05; **p<0.01; ***p<0.001; NS, not significant playing status; and, 2- emphasizes some of the top elite anthropometric measures like basic measures, arm lengths, arm girths, muscle mass and reduced fat tissue.

Stepwise discriminant analysis

To determine which combination of measures best discriminated the different levels of performance, for the whole sample and for each playing position group, a stepwise discriminant analysis was used. In accordance, the discriminant analysis showed that: 1- goalkeeper groups were successfully discriminated by a combination of four variables (for which 73.5% of the originaly group cases and 47.1% of the cross-validated grouped cases were correctly classified); 2- wing groups were successfully discriminated by a combination of three variables (for which 43.1% of the originaly group cases and 40.0% of the cross-validated grouped cases were correctly classified); 3- backward left/rigth groups were successfully dicriminated by muscle mass (for which 34.8% of the originaly and cross-validated grouped cases were correctly classified); 4- backward center groups groups were successfully discriminated by four measures (for which 73.7% of the originaly group cases and 65.8% of the cross-validated grouped cases were correctly classified); 5- pivot groups were successfully discriminated by two variables (for which 57.1% of the originaly group cases and 35.7% of the cross-validated grouped cases were correctly classified). Finally, all five playing positions were analyzed together and discriminant analysis showed that a combination of six variables successfully discriminated level of performance groups (fat mass and muscle mass were the variables that better distinguished between groups and classification results showed that for which 47.6% of the originaly group cases and 41.5% of the cross-validated grouped cases were correctly classified). The results of all stepwise discriminant analysis were presented in Table-4 and are graphically represented in Figure-1.

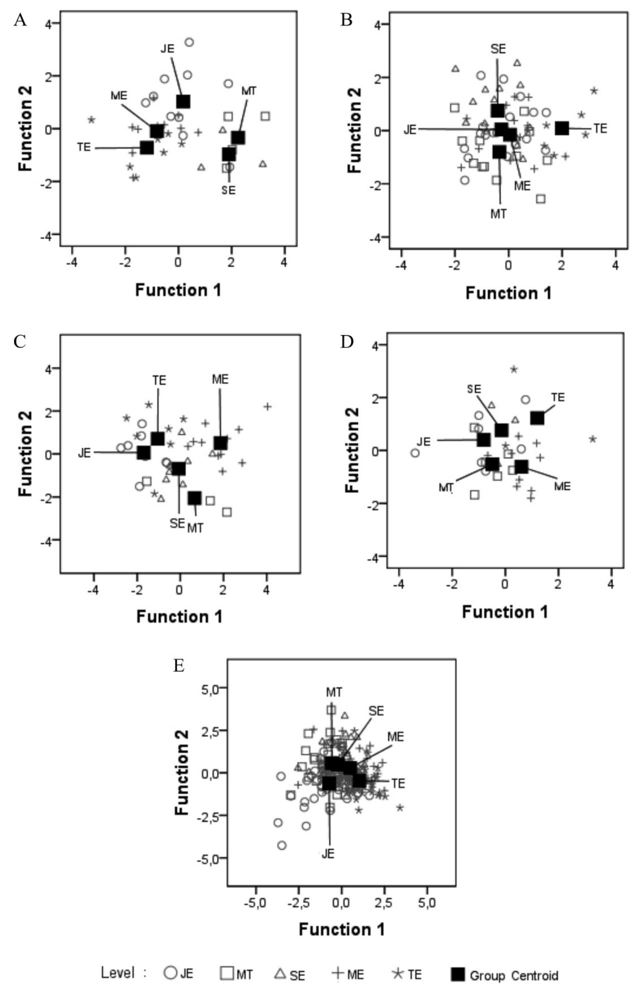

Fig. 1. Canonical Discriminant Funcions (Scatter-plot) of A) goalkeeper groups, B) wing groups, C) backward center groups, D) pivot groups and E) for all five playing position groups.

Discussion

Despite the diversity of investigation lines within this area, sport performance research can be structured based on two different perspectives. The first, focused on morphological optimization (i.e., development) and on the analyses and comparison of all senior playing status (MT, SE, ME and TE). This observation revealed that top elite players were morphological different from all the others status groups, particularly, from the moderate trained players. In other words, results suggested that top elite athletes have bigger bodies and hand sizes, bigger linear dimensions and higher muscle mass and free fat mass.

The second, focused on talent selection process and on the analysis of the junior elite and top elite (professional) handball players. These particular groups were also morphological different. In fact, results showed one more time the morphological superiority of top elite athletes (i.e., size, lengths, muscle mass and free fat mass).

Many authors have written about morphological optimization and success in sports[37,38]. However, little has been written about morphological optimization for different playing positions[16,39–43]. In fact, and in accordance with the literature, handball players have different anthropometrical profiles according to playing positions[15–17]. This can be observed (indirectly) through the different combinations of morphological variables that discriminate the different levels of performance for each game position.

In general, top elite players showed higher basic measures, higher longitudinal and transverse dimensions of the upper limbs (i.e., girths, breadths and upper limb lengths), and more muscle mass and less fat tissue. Players from higher playing status were taller and had lower body fat. These results clarified not only the relation between different levels of performance but also confirmed the requirements for being an elite handball player[11,13,18,20].

Stature and body mass showed significant differences between players from different levels of performance, and these differences were all in favor of the top elite players (TE; Range: stature =+5.08 cm to 8.68 cm; body mass

TABLE 4
STANDARDIZED CANONICAL DISCRIMINANT FUNCTION COEFFICIENTS, EIGENVALUES AND VARIANCE

Variables / Function	All Playing Positions[a]				Goalkeeper[b]				Wing[c]			Backward Left/ Right[d]	Backward Center[e]				Pivot[f]	
	1[a]	2[a]	3[a]	4[a]	1[b]	2[b]	3[b]	4[b]	1[c]	2[c]	3[c]	1[d]	1[e]	2[e]	3[e]	4[e]	1[f]	2[f]
Biceps skinfold (mm)													–0.662	–0.564	0.762	0.056		
Medial calf skinfold (mm)	–0.633	–0.580	0.666	–0.082	2.229	0.432	1.908	–0.213										
Chest girth (cm)					2.301	–1.596	1.463	–0.009					1.259	0.309	0.393	–0.254		
Biacromial breadth (cm)																	–0.222	1.111
Acromiale-dactylion length (cm)									0.652	0.165	–0.841		–1.332	0.776	0.188	0.008		
Radiale-dactylion length (cm)	0.214	–0.045	0.814	–0.452														
Midstylion-dactylion length (cm)													0.996	–0.137	–0.146	0.954		
Muscle mass[34] (kg)	0.670	–0.501	–0.743	–0.618					0.826	–1.203	0.433	1.000						
Muscle mass[21] (kg)									–0.289	1.442	0.546							
Muscle mass (1st Equation)[36] (kg)					–1.472	0.536	0.360	0.087									1.085	–0.327
Muscle mass[33] (%)	0.123	0.536	1.039	–0.019														
Fat mass[28] (kg)					–2.991	0.762	–2.905	1.143										
Fat mass[29] (kg)	0.689	1.461	0.313	0.422														
Fat mass[25] (%)	0.400	0.536	0.445	1.421														
Eigenvalues	0.454	0.251	0.094	0.019	1.641	0.605	0.252	0.008	0.548	0.267	0.053	0.592	2.160	0.706	0.307	0.022	0.600	0.540
% of variance	55.5	30.7	11.5	2.3	65.5	24.1	10.1	0.3	63.1	30.8	6.1	100.0	67.6	22.1	9.6	0.7	52.6	47.4

Test of function(s):

All playing positions: 1st – Wilks' Λ=0.493, $\chi^2(24)$=144.542, p<0.001; 2nd – Wilks' Λ=0.717, $\chi^2(15)$=67.952, p<0.001; 3th – Wilks' Λ=0.897, $\chi^2(8)$=22.186, p=0.005; 4th – Wilks' Λ=0.981, $\chi^2(3)$=3.823, p=0.281;

Goalkeeper: 1st – Wilks' Λ=0.187, $\chi^2(16)$=47.791, p<0.001; 2nd – Wilks' Λ=0.494, $\chi^2(9)$=20.114, p=0.017; 3th – Wilks' Λ=0.792, $\chi^2(4)$=6.638, p=0.156; 4th – Wilks' Λ=0.992, $\chi^2(1)$=0.227, p=0.634;

Wing: 1st – Wilks' Λ=0.484, $\chi^2(12)$=43.515, p<0.001; 2nd – Wilks' Λ=0.750, $\chi^2(6)$=17.299, p=0.008; 3th – Wilks' Λ=0.950, $\chi^2(2)$=3.087, p=0.214;

Backward left/rigth: Wilks' Λ=0.628, $\chi^2(4)$=19.523, p=0.001;

Backward center: 1st – Wilks' Λ=0.139, $\chi^2(16)$=64.151, p<0.001; 2nd – Wilks' Λ=0.439, $\chi^2(9)$=26.762, p=0.002; 3th – Wilks' Λ=0.749, $\chi^2(4)$=9.398, p=0.052; 4th – Wilks' Λ=0.979, $\chi^2(1)$=0.699, p=0.403;

Pivot: 1st – Wilks' Λ=0.406, $\chi^2(8)$=21.193, p=0.007; 2nd – Wilks' Λ=0.649, $\chi^2(3)$=10.151, p=0.017.

=+3.98 kg to 8.41 kg). These global results are in accordance with the results of Eston and Reilly[2] and Reilly[40] who considered the body mass and stature very important to achieve a high level of performance in throwing events and in accordance with Bayer[44], Seco[45] and Garcia et al.[46], who observed that most successful teams have a very high mean stature. Also the body mass appears to be essential, especially in one-to-one situations[47] and for this reason most of the National players are very heavy[44].

In what respects arm span, it seems that this measure can help on the execution of a shot (because the larger the radius of action the greater the power of the technical gesture) and on some defensive actions (e.g., block).

Similarly handling the ball (with only one hand), is particularly important so according to Fischer et al.[48] a higher hand span (between 24–26 cm) can helps in some handball-specific skills. Although there is evidence that the mean score of hand span in the top elite level of performance was greater, this measure was less than 24 cm, suggested by the authors as a reference value (i.e., TE hand span =23.12 cm; see Table-2).

In the study of body composition, the use of various equations described in the literature as fundamental for the body composition assessment of handball athletes allowed us: 1- to study the different equation behavior; 2- to compare the obtained differences (between equations); and 3- to identify what were the equations most suitable to discriminate the different levels of performance (i.e., Heymsfield et al.[34]; Lee et al. – 1st eq.[36]; Jackson & Pollock[29]; Durnin & Womersley[25]). Furthermore, the percentage of muscle mass resulting from the application of the second equation of Lee et al.[36], contradict the results of the literature and of other equations. However, we remember that this equation is for obese subjects, not for athletes, as the authors made clear. In fact, a careful analysis of the variables included in this equation revealed that, unlike other prediction equations, this one uses (only!) the stature and body mass of the subject as explained variable. For this reason, we insist that the analysis of the results should be carefully made.

In continuation, the results of body composition consistently showed that the top elite players have more muscle mass (Range: absolute =+9.82 kg to +1.41 kg; relative =+6.99% to –1.79%), more free fat mass (Range: absolute =+15.01 kg to +4.23 kg; relative =+10.22% to +0.98%) and less fat mass (Range: absolute =–1.51 kg to –6.61 kg; relative =–4.32% to –0.34%). The time spent on sport is directly related with body fat mass[49,50], i.e., the greater the level of fitness[51], the lower should be the level of adiposity[52,53]. These results also emphasize the importance of exercise as a regulation factor of body changes[54,55].

It is clear that in athletes, a minimal amount of body fat reduces the excess weight carried during the jumping and running actions[56]. In this study, it was also patent that handball athletes with higher competitive levels had (on average) lower percentage of fat mass, although the mean value of the studied groups matched, in general, with the values (>4%; <12%) reported in literature[51,57–60].

Sports that require jumping and running (as handball), need higher porportion of muscle mass to increase not only their strength but also but also their power[51], but not too much or they will not run or jump with the same ease (i.e., between 45% and 55%, as sugested by our results; see Table 3). In accordance, most athletes need a high strength-to-weight ratio to achieve optimal athletic performance, and because body fat adds to weight without adding to strength, low body fat percentage is often emphasised as a requirement within many sports[61]. Therefore it is reasonable to observe that the free fat mass (absolute) of athletes of different competitive levels differ significantly, i.e., the best players (top elite) were also significantly more robust[18,44,60] (see Table-3).

The differences between levels of performance and the discriminant analysis results (Table-3), emphasizes the relevance of an appropriate morphological profile according to the athlete specificity in the team structure. Thus, it is clear that the level of performance can be discriminated by particular morphological characteristics, i.e., 1- goalkeepers based on high linearity, high muscle mass and low fat mass, 2- wings, backwards left/right and pivots based on high muscle mass (more strength and power), and 3- backwards center based on bigger acromiale-dactylion length and trunk measures (strong and agile). So, the research findings showed that the level of performance was related with physical characteristics and that size, shape and body composition could provide the strutural conditions to be sucessful at each specific playing positions. They also showed that morphological characteristics were markedly different among the studied groups and among the handball positons. Moreover, upper limb lengths (and girths) and body composition were the variables that most contributed to optimal performance.

Conclusion

The study of handball player revealed that this sport requires a certain kind of athlete and that individual participation is just possible when a set of anthropometric characteristics is present. The relation between different levels of performance and some morphological requirements was observed as well as it was evident that each playing position was related to a particular morphological profile. Nevertheless, some discriminant analysis results were not very encouraging (e.g., backward left/right players), suggesting, in the near future, the use of a multidisciplinary approach.

Moreover, the morphological approach can be an important »key« factor to achieve good results along a complex process of talent selection in sport. So we believe that this particular approach can contribute to the morphological optimization process (i.e., development) and to talent selection process of handball Portuguese players. In accordance, future analyses should consider other areas such as physiology, psychology, biosocial, tactical and thecnical skills to provide an even more comprehensive knowlege of the requirements to achieve high levels of performance in handball.

Another important conclusion and suggestion, although methodological, concerns to the set of equations chosen when body composition of handball players, with different levels of performance, is evaluated. The results (discriminant analysis) showed that the Heymsfield et al.[34], Lee et al.[36] (first equation), Jackson and Pollock[29], and Durnin and Womersley[25] equations can be used to discriminate handball players from different levels of performance. However it is important to highlight that the original anthropometric measures of some of these prediction equations, do not adopt the anthropometric sites described by ISAK anthropometric protocol. This methodological effort, may help in the near future to the construction of a Handball Success Model.

Finally, we would like to say that we are aware that working with five performance levels and five game positions increases the variance of the sample that could be reduced reducing the number of groups by combining some groups of performance. This can be a future possibility. Meanwhile, the methodological adopted allowed us to present results consistent with the Portuguese reality and reveal the morphological differences among all levels of performance considering the Portuguese handball reality. We also know that we used, to assess body composition, indirect and less precise methods. However, from this work and because we used different indirect methodologies, as would be desirable, we may from now, in the near future and with a smaller sample, compare the methodologies of body composition chosen as discriminants with more accurate ways to measure athletes' body composition.

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MORFOLOŠKE KARAKTERISTIKE ODRASLIH RUKOMETAŠA S OBZIROM NA PET RAZINA IZVEDBE I POZICIJU U IGRI

S A Ž E T A K

Ova studija ima za cilj 1 – opisati i usporediti antropometrijska obilježja muških rukometaša iz različitih razina izvedbe, te 2 – identificirati morfološke varijable koje omogućuju razlikovanje razine izvedbe za svaku pojedinu poziciju u igri. Ukupno 212 muških rukometaša (dob, 23,6±5,2 godina) bilo je uključeno u ovu studiju, a za usporedbu su podijeljeni na pet razina izvedbe. Evidentirana je pozicija u igri svakog igrača. Svi su sudionici bili testirani tijekom portugalske rukometne sezone 2008–2009. Grupa antropometrika, akreditiranih od strane Međunarodnog društva za napredovanje kinantropometrije, uzela je dvadeset i osam antropometrijskih mjera. Sastav tijela, masnog tkiva i mišićne mase izračunate su iz jednadžbi koje predlažu Faulkner[26], Yuhasz[28], Durnin i Womersley[25], Jackson i Pollock[29], Matiegka[33], Heymsfield, McManus, Smith, Stevens i Nixon[34], Martin, Spenst, Drinkwater i Clarys[21], Doupe, Martin, Searle, Kriellaars i Giesbrecht[35] i Lee, Wang, Heo, Ross, Janssen i Heymsfield[36]. Rezultati istraživanja su pokazali da je morfološka optimizacija važna za uspjeh u rukometu.